CEMENT AND LIME MANUFACTURE

PUBLISHED 20TH OF EACH MONTH. PRICE 1/- A COPY. ANNUAL SUBSCRIPTION 12/- POST FREE

PUBLISHED BY
CONCRETE PUBLICATIONS LIMITED
14 DARTMOUTH STREET, LONDON, S.W.1

TELEPHONE: WHITEHALL 4581.
TELEGRAPHIC ADDRESS:
CONCRETIUS, PARL, LONDON

PUBLISHERS OF
"CONCRETE & CONSTRUCTIONAL ENGINEERING"
"CONCRETE BUILDING & CONCRETE PRODUCTS"
"CEMENT & LIME MANUFACTURE"
"THE CONCRETE YEAR BOOK"
"CONCRETE SERIES" BOOKS, ETC.

VOLUME XVI. NUMBER 10 OCTOBER 1943

Ten-Year Tests of Masonry Cements.

When an investigation into the properties of masonry cements was made by the United States National Bureau of Standards (reported in Research Paper No. 746, 1934), a number of test pieces were stored with the object of observing their behaviour after storage for ten years in air and in water. The long-period tests were made on 2-in. cubes of the following compositions: (A) 1 part cement to 3 parts standard sand by weight; (B) 1 part cement, 2 parts standard sand and 1 part fine testing sand (all measured by weight); and (C) as (B) except that the materials were measured by volume. Various types of cement were used, classified in groups as follows: P = Largely Portland cement; PL = Portland cement and hydrated lime mixtures; PM = Portland cement mixed with unidentified materials; PN = Portland cement and natural cement mixtures; N = Natural cement; S = Large amount of slag; U = Not identified; HL = Hydraulic or hydrated lime. In all the mortars, the amount of water required for normal consistency (a flow of 100 to 115 on the standard 10-in. flow table) was used. The sand and cement were mixed dry, water was added, and mixing continued for five minutes. The mortars were allowed to stand 14½ minutes and were again mixed for half-a-minute.

The 2-in. cubes were stored in a damp closet for two days in the moulds, after which they were removed from the moulds and stored in the damp closet for an additional five days. The specimens were then stored in water, and after seven days half of the specimens were removed and stored in laboratory air until tested. The cubes were tested in compression at 7 days, 28 days, 3 months, 1 year, and 10 years. Three specimens were tested at each age after both water and air storage.

Length measurements were made every week for one month, then every month for one year, and then at ten years on 1 in. by 1 in. by 8 in. mortar bars. These specimens, after seven days in the damp closet, were stored in

water until measured. The companion bars stored in air were not measured, as the glass plates that formed the ends of the bars had been broken off in many instances.

Compressive Strength.

The ten-year compressive-strength tests of cubes (A) showed that all the cements classified in the natural (N) or slag (S) groups had greater compressive strength after water storage than after air storage. All the cements of the Portland (P) group, 8 of 10 of the cements of the Portland-with-unidentified-materials (PM) group, and 7 of 8 of the Portland cement-hydrated lime (PL) group had greater strength after air storage than after water storage. In the case of the pairs of cements of the types Portland-natural (PN), hydraulic or hydrated lime (HL), and unidentified (U), one specimen of each type had greater strength after water storage, whereas the other specimen of each type had greater strength after air storage. Both the specimens made with U cement, 1 of 2 PN, 1 of 2 HL, 3 of 4 N, 1 of 6 S, 1 of 10 PM, and 2 of 8 PL cements had compressive strengths of less than 1,000 lb. per sq. in. after ten years of air storage. After ten years of water storage, 2 of 2 U, 1 of 2 PN, 1 of 4 N, and 5 of 8 PL cements had compressive strengths less than 1,000 lb. per sq. in. Only six of the cements had compressive strengths of 1,000 lb. per sq. in. or less with both storage conditions. After ten years of water storage, 17 of the 41 cements had compressive strengths of 2,000 lb. per sq. in. or greater, and 18 cements had compressive strengths of 2,000 lb. per sq. in. or greater after air storage. Fourteen of the cements had 2,000 lb. per sq. in. or greater compressive strength with both storage conditions.

Specifications for masonry cements require compressive-strength tests at only seven and 28 days. However, some types of cement have different rates of strength increase when exposed to damp or to dry conditions, and some types of masonry cement increase in strength and others do not. An analysis was made of the relation of the 1-year and 10-year compressive-strength values after both water and air storage to the values obtained at 28 days. Unless otherwise stated, the discussion is confined to mortar (A), which corresponds with the mortar required in the masonry cement specification tests both as to proportions and storage conditions up to 28 days.

The cements classified as Portland (P) cements had 28-day compressive strengths of over 2,000 lb. per sq. in. and increased only slightly in strength after one year of water storage. There was a decrease in strength between one and ten years of water storage with every cement. On the other hand, the specimens stored in air increased in strength to 1·4 and 1·8 times the strength value of the 28-day water-stored specimens at one and ten years respectively. Specimens made with a grappier cement, which was originally classified as a Portland cement, had 28-day strengths less than the other cements of the group, whereas the strength increases at one and ten years were greater.

Six cements of the PL group had 28-day compressive-strengths of 500 lb. per sq. in. or less. The other two had 28-day compressive-strengths of 1,200 lb. per sq. in. more. The strengths after one year of water storage were about 1·5

times the 28-day values for all of the cements of this group; only one increased slightly in strength from one to ten years, whereas six indicated a slight decrease. The compressive strength after one year of air storage was about 2·0 times, and at ten years 2·7 times, the values obtained for the 28-day water-stored specimens.

Nine of ten cements of the PM group had 28-day compressive strengths of about 1,000 lb. per sq. in. or greater. The cements of this group had compressive strengths after one year of water storage of 1·4 times the values obtained for the 28-day water-stored specimens. Only two of the ten cements had further strength increases between the period of one and 10 years of water storage, and seven of the ten cements had slight strength decreases in the same period. After air storage for one and ten years the respective compressive-strengths were 1·6 and 1·8 times the 28-day strength values of water-stored specimens. One specimen had a 28-day compressive strength of 650 lb. per sq. in., and the compressive strength of the specimens stored in air was only slightly higher at one year, whereas at ten years the value had decreased slightly. One other cement in this group had a slight strength decrease between one and ten years in air storage.

Five of six of the slag (S) cements had 28-day compressive-strengths of 500 to 1,000 lb. per sq. in. After storage in water the strength values were 2·0 and 2·8 times the 28-day values at one and ten years respectively. In air storage, however, the one-year compressive-strengths were about 2·0 times the 28-day values, and only one of the six cements had an increase in strength between one and ten years, whereas four of the six decreased in strength in the air storage. One of the six cements of this group decreased in strength between one and ten years in both wet and dry storage.

Of the two cements of the PN group, one had a compressive strength of 170 lb. per sq. in. after 28 days of water storage, but increased to 2·3 and 5·7 times the 28-day value at one and ten years respectively when stored in water. After ten years of storage in air the compressive strength was 2·3 times the values of the 28-day water-stored specimens. The other cement had a compressive strength of 750 lb. per sq. in. at 28 days, and the strength after one year of water storage was 2·5 times this value. The compressive strength decreased slightly between one and ten years of water storage. The compressive strength at one and ten years of air storage were 2·1 and 2·9 times the values for the 28-day water-stored specimens.

One of the cements of the HL group had a 28-day compressive strength of 400 lb. per sq. in., and the respective 1-year and 10-year values for water-stored specimens were 3·4 and 4·6 times, whereas the air-stored specimens were 2·4 and 3·9 times the 28-day strengths. The other cement of this group had a 28-day compressive strength of 220 lb. per sq. in. Water-stored specimens were only slightly stronger at one year than at 28 days, and at ten years the strength was the same as at 28 days. The compressive strengths of the air-stored specimens were 2·3 and 3·7 times the 28-day values at one and ten years respectively.

The two cements of the U group had 28-day strengths of less than 100 lb. per sq. in. Both cements had a high percentage increase in strength when stored

in water. The compressive strengths of the air-stored specimens were 1·9 and 2·3 times the 28-day values at one and ten years respectively.

Effect of Proportions on Strength.

A comparison was made of the strength increases at one and ten years of both water-stored and air-stored specimens of mortars (A) made with standard sand and (B) made with the graded sand. With many cements there was slight, if any, difference in the strength increase of the two mortars, whereas with other cements there were appreciable differences. No well-established trend was observed. It was noted in comparing these two mortars that (B) had, in almost every instance, greater 10-year compressive strength than the corresponding mortar (A).

A comparison was also made of the ratio of compressive strengths at ten years and 28 days of mortars (A) and (C) proportioned 1·3 by weight and by volume respectively. The leaner specimens had the greater strength increases between 28 days and ten years of water storage in 27 of 33 cements. These were divided as follows: 7 of 7 PL, 8 of 10 PM, 6 of 6 S, 1 of 4 N, 1 of 2 PN, 2 of 2 HL, and 2 of 2 U. With air storage the leaner specimens did not have so great a strength increase as the 1·3 by weight specimens. This was true in 30 of 33 cements, and these were apportioned as follows: 6 of 7 PL, 9 of 10 PM, 4 of 4 N, 5 of 6 S, 2 of 2 PN, 2 of 2 HL, and 2 of 2 U. No trend was noted with the Portland cements, possibly because the 1·3 proportions by weight and by volume were more nearly the same.

Length Measurements.

Length measurements on the bars made of mortar (A) of normal consistency stored in water for ten years suggest that there is a definite trend of greater expansions with cements of higher magnesia content. Although the bars made from cements having less than 4 per cent. of magnesia all had linear expansions of less than 0·4 per cent. in ten years, and those made from four of the cements having a high magnesia content had linear expansions of from 0·265 to 0·808 per cent., nevertheless, mortars made from three cements having a high magnesia content expanded only from 0·05 to 0·09 per cent.

It is impracticable to require specification strength tests at periods greater than 28 days. However, the 28-day results are not indicative of the strengths that may be expected unless something is known of the composition of the cement. Consideration should also be given, especially with low-strength cements, to the conditions under which the mortar is to be used. For example, many of the cements which were originally classified as Portland cement-hydrated lime mixtures had relatively low compressive strength even after ten years of water storage. On the other hand, some of the natural cements had low compressive strengths after ten years of air storage. The storage conditions of the investigation are not the same as those under which the mortars are used, but cognisance should be taken of the fact that some of the cements do not have a great increase in compressive strength after 28 days under certain conditions. Many of the

mortars made of these cements decrease in strength between one and ten years with one or other of the storage conditions of the investigation.

The presence of unhydrated, or free, magnesia in cementitious materials has long been recognised as contributing to unsoundness because of the expansion concomitant with the hydration of the oxide to the hydroxide form. Masonry cements are sometimes made by the addition of either slag, hydrated dolomitic lime, or finely-ground dolomitic limestone to a Portland cement for purposes of plasticising or diluting the cement. Accordingly, in many cases the magnesium compounds may not be of the unhydrated form, e.g. some may be in the form of carbonate from the limestone, and some may be completely hydrated, since completely hydrated limes are now available. Therefore, inasmuch as the character of the magnesium compound is significant, it would be unfair, with masonry cements, to limit the percentage of total MgO content as determined by chemical analysis. In the investigation, mortars of four of the seven cements of high MgO content expanded considerably more than the other three of this group, indicating that the total MgO content, as determined by chemical analysis, is not a criterion of expansion. The determination of the free, or unhydrated, magnesia in mixtures such as masonry cements would be impractical, if not impossible, and it therefore appears that the only method of safeguarding against excessive expansion would be the adoption of an autoclave expansion test such as is required in Portland cement specifications.

Summary.

The compressive strengths of 1·3 masonry cement and standard sand mortars varied from less than 200 to more than 6,000 lb. per. sq. in. at ten years. Mortars made of cements originally classified as largely Portland, Portland-plus-unknown additions, and Portland-lime mixes had greater compressive strength after ten years of air storage than after ten years of water storage; mortars of these types of cement had very little increase or a slight decrease in compressive strength between the period of one and ten years of water storage but had appreciable strength increases in air storage for the same period. Mortars made of cements originally classified as natural cements or largely slag cements had greater compressive strength after water storage than after air storage for ten years; mortars of these cements had appreciable compressive-strength increases in water storage between the 1-year and 10-year periods. Mortars made of natural cements increased only slightly in compressive strength, whereas those made with slag cements decreased slightly between the 1-year and 10-year periods of air storage.

Mortars made with graded sand maintained a higher compressive strength than mortars made with standard sand with most of the cements after ten years. At ten years the leaner mortar (C) had greater strength increase with water storage and smaller increase with air storage than standard 1·3 mortar compared with the 28-day compressive strengths. The percentage of water used in preparing the mortars did not alter to a great extent the ratio of the compressive-strength increases between 28 days and ten years.

The linear expansion of mortar specimens at ten years varied from 0 to 0·808 per cent. There was a definite trend of greater expansion with greater magnesia content of the cement. All mortar specimens made of cements having less than 4 per cent. of magnesia had linear expansions of less than 0·04 per cent. during ten years of water storage. Conversely, mortars made of four of seven of the cements with the highest magnesia contents had expansions greater than 0.25 per cent.

Vinsol Resin as a Cement "Improver."

SOME tests made by Messrs. E. O. Axon, T. F. Wills, and F. V. Reagel (of the Missouri State Highway Department) on the use of vinsol resin for the improvement of concrete made with inferior aggregates were described at the 1943 annual general meeting of the American Society for Testing Materials.

Four different coarse aggregates were used, two limestones and two chert gravels. Concretes having air-contents of approximately 1, 4 and 7 per cent. were tested. A normal Portland cement gave an air content of 1 per cent., and cement ground with 0·1 per cent. of vinsol resin was blended with the normal cement to give the air contents of 4 and 7 per cent. Concrete prisms 3½ in. by 4½ in. by 16 in. made from the different mixes were tested in flexure at the age of 35 days, and three or more sets of four prisms each were subjected to freezing and thawing tests of two types.

The conclusions reached were: The use of vinsol resin as an air-entrapping admixture has certain definite effects on concrete. For concrete in the plastic state it makes the mixture "fatter," improves workability, and reduces "bleeding" and water gain. For concrete in the hardened condition it reduces the flexural strength and dynamic modulus, at least up to 35 days, but apparently has little, if any, effect on the thermal coefficient of expansion.

The information obtained from freezing and thawing tests was considered to indicate certain trends, summarised as follows: (1) Vinsol resin as an air-entrapping admixture caused no appreciable improvement in the durability of concrete containing chert gravel of such characteristics that its use in road concrete had resulted in roads of poor durability. (2) In the case of chert gravel of such characteristics that its use in concrete had resulted in a fair service record, there is disagreement between the indications of the two freezing and thawing test procedures, which raises the question of the validity of the results of either or both procedures. There is only a slight chance that vinsol resin will benefit concrete containing aggregate of this kind, but this chance, and also the possibility that increasing the initial flexural strength will produce concurrent benefits, should be investigated. (3) The entrapment of air improved the durability of concretes containing either of the two limestones.

Reactions Between Cement and Aggregates.

As was mentioned in this journal for June, 1942, some failures of concrete have been traced to the reaction between Portland cement and aggregates which had passed all the usual tests. Investigations into this problem have been made during the past two or three years, particularly in the United States where the failures occurred, and these investigations have been summarised and discussed by the Australian Council for Scientific and Industrial Research in a paper (Bulletin No. 161) by Dr. A. R. Alderman, M.Sc., Ph.D., F.G.S. The Council has recently formed a section for the investigation of problems relating to cement, towards the cost of which the Australian Cement Manufacturers' Association is contributing, and Dr. Alderman's paper is a preliminary to an investigation on the reaction between cement and certain types of aggregate. As the subject is a new one, we give the following abstract of the author's summary of the work so far done in this connection.

The suggestion that cracking and other deterioration of concrete might be due to reactions taking place between aggregate and cement first became prominent early in 1940. Mr. T. E. Stanton had in that year described how the combination of certain aggregates with high-alkali (the word " alkali " is used to denote the common alkali-metals, potassium and sodium) cement had apparently led to the cracking of stretches of concrete road in California. Additional prominence was given to the matter when the concrete of Parker Dam showed signs of serious deterioration two years since its completion ; the defects were again attributed to reactions between certain constituents of the aggregates and cements rich in alkali.

Mr. Stanton's attention was drawn to the problem through the expansion and failure of certain stretches of concrete road in California in 1938. The road, which had been built in 1936–1937, showed buckling at the expansion joints and cracking throughout the slabs. The coarse aggregate came from a river bed, whereas the sand came from two sources, Oro Fino and Coyote. These sands were used on alternate stretches, and it was only those in which Oro Fino sand was used that showed excessive expansion. Another such failure, quoted from many, is in the King City Bridge, in which the concrete of the piers developed severe cracking, whereas that in other parts has remained sound. The two concretes, so far as is known, differed only in the sands used. Throughout the region where such failures have been noted, the common aggregate materials are of the same general type and may contain 4 to 15 per cent. of shale, cherty shale and chert. It appears that these failures all started through excessive expansion of the concrete. The problem was complicated by the fact that although, without exception, such cracking was associated only with these aggregates, there were numerous instances where apparently the same aggregate had been entirely satisfactory.

Mortar and concrete bars were made using the apparently unsatisfactory (Oro Fino) aggregate and the satisfactory (Coyote) aggregate. Even after a

year of curing no excessive expansion was shown by test bars subjected to continual wetting, to dry exposure, to alternate wetting and drying, or to a variety of such treatments, except with an aggregate consisting entirely of shale, in which failure was probably due to other causes. Symptoms of failures were, however, reproduced in test bars which had been stored moist for a year in sealed containers, which ensured retention of the original mixing water without additions or subtractions, and thus reproduced conditions which might be expected in large masses of concrete. Excessive expansion was found only when aggregates (like Oro Fino) containing appreciable amounts of shale, chert, or impure limestone were used with high-alkali cement. Furthermore, the expansion was roughly proportional to the alkali content of the cement. On the other hand, if these sands are used with cement containing less than 0.5 per cent. total alkali there is no abnormal expansion. No expansion is noted when high-alkali cements are used with sands containing only negligible amounts of the trouble-causing ingredients.

The aggregates which cause expansion are made up predominantly of particles of granite, quartz-felspar, and sandstone, which together constitute about 90 per cent. of the whole. None of the adverse reactions has been traced to these constituents. The remaining 5 to 10 per cent. comprises particles of impure limestone, shale and chert. It is to these constituents that suspicion is attached. They are derived from rocks of the Monterey Series of Upper Miocene age, which are widespread in this part of California, but said to be of unique petrographical nature. Opaline silica is a common constituent of the shales, cherts and limestones in this series of rocks. An effort has been made to study those constituents which are dangerous when used with high-alkali cements. The greatest expansion was produced by material classified as siliceous-magnesian-limestone which caused trouble even when present in percentages less than 1.0. Stanton found that it is opal which is the reactive component. The Merriman tests for alkalinity and free alkali were not found to give an index of the expansive potentiality of cements. More than 3,000 test bars were measured, and the results confirmed that dangerous expansion occurs only when a high-alkali cement is used in combination with an aggregate containing opaline silica.

Examination of " blows " in concrete structures shows that gelatinous silica and sodium silicate are produced by the alteration of particles of shale or chert. It is suggested that such gels may be formed by reaction between cherts and cherty shales and alkali hydroxides, supposedly present in high-alkali cement after hydration.

Cracks in a Large Dam.

In the construction of Parker Dam four brands of low-heat-type Portland cement were used having alkali contents as follows : $Na_2O = 0.13$, $K_2O = 0.42$; $Na_2O = 0.82$, $K_2O = 0.31$; $Na_2O = 0.69$, $K_2O = 0.56$; $Na_2 = 0.81$, $K_2O = 0.61$. In the portion of the dam exposed to view only one brand of cement was used—that having the highest percentage of alkalis. The aggregates were thoroughly tested and seemed to be well above the average in their physical and concrete-

making properties. The dam was completed in 1938. In 1940 cracking became evident and progressed rapidly. The concrete has been investigated by drilling boreholes of depths up to 87 ft., installing instruments to measure movements, and by examination of the drill-cores. The surface cracks extended a depth of only 6 in. to 8 in. ; this would be about the depth of complete surface drying of the concrete at the time of measurement, which apparently produced a shrinkage in the outer shell. In the interior, where residual mixing-water is still available, a measurable expansion was in progress. Examination of drill-cores stored in the presence of moisture showed that a gel-like substance, consisting largely of sodium silicate, exuded from the surface of the core. It appears that the sodium silicate is produced by a reaction between the sodium compounds in the cement and siliceous minerals contained in particles of aggregate. In the presence of moisture this reaction seems to be accompanied by an increase in volume, and thus produces an expansion of the concrete mass. This reaction does not, apparently, proceed with all types of rock in the aggregate, but is confined to particles of altered andesite and rhyolite, particularly with fragments of andesite which contain small veins of opal as well as chalcedony and quartz ; the andesite and rhyolite constitute less than 2 per cent. of the total aggregate. Tests on mortar bars stored in the presence of moisture, and made with Parker Dam aggregate and high-alkali cement, showed an expansion of 0.05 per cent. in sixteen weeks. Lower expansions have been obtained with a cement of lower alkali content. Mortar bars made of high-alkali cement and of different aggregates show negligible expansions.

Investigations made on other concrete structures where expansion has occurred suggest that the trouble is due to the same cause.

Later Investigations.

In continuation of his earlier paper, Stanton gives additional results of laboratory experiments. Test bars made from high-alkali cement and Oro Fino coarse aggregate expanded after two years of moist storage ; it was formerly believed that only the fine aggregates were dangerous. Evidence also shows that expansion produced by siliceous magnesian limestone is almost entirely due to its opal content. Test bars which contain excessive amounts of opal may also show less expansion than others in which the opal content is smaller. It is also suggested that opal with a high water content is more reactive than that with a low water content, and that only cherts with silica in the opaline form are dangerous. Chalcedonic cherts free from opal seem to be reasonably safe.

Attempts have been made to find correctives for expansion. The only substance which gave encouraging results was pozzolanic material when substituted for part of the cement. Attempts to develop correctives are described by Meder, who suggests that the reactivity of high-alkali cement may be due to the presence of sodium hydroxide. The addition of correctives should therefore aim at the elimination of the hydroxides of the alkali metals. Disappointing results were obtained with bars to which varying amounts of $CaCl_2$, $FeCl_3$, $AlCl_3$, NaCl, KCl, diatomaceous earth, $MgCO_3$, sodium alginate, vinsol resin,

and Na_2SO_4 had been added. Expansion was reduced by adding small amounts of aluminium powder. The most encouraging results were obtained by the addition of siliceous and pozzolanic materials to the cement. Other experiments seem to show that the reactive effects of the hydroxides of sodium and potassium are approximately equal. There are also indications that if the alkali content of the cement is greater than a certain amount, the action may even be retarded instead of accelerated.

Although observations of structures and of specimens have shown that the combination of high-alkali cement with dangerous aggregate may cause expansive reaction, the same observations have also shown that similar reaction is unlikely when such cement is used with aggregates free from the dangerous constituents. Expansion is also unlikely when low-alkali cement is used even with dangerous aggregate, although an instance has been described where expansion seems to have taken place without any assistance from the alkali components of the cement.

The dividing line between high- and low-alkali cements is a controversial point. The California Division of Highways modified its specifications for cement to be used where local aggregates are regarded as dangerous. The specifications limited the total alkali-content to 0.50 per cent., the word alkali being used for the sum of Na_2O and K_2O calculated as Na_2O. The figure was later raised to 0.60. Stanton states that the expansion is so small as to be negligible when the alkali-content of the cement is less than 0.60 per cent. The figure by which cements are judged as being low in alkalis is likely to lead to many anomalies. No consideration is given to the possibility that potassium and sodium may have somewhat different effects. In cement clinker there is good evidence to show that potassium is combined in at least two different ways. These potassium-containing compounds probably differ in their readiness to react with aggregates. Similar remarks may well apply to sodium, and these points are supported by the variable water-solubility of the alkali-constituents of cement. It is thus not necessarily true that a cement containing 0.4 per cent. total alkali will have less alkali in potentially reactive form than a cement which has a total content of 0.8 per cent. Until more is known about the chemistry of the alkali metals in cement these matters will remain uncertain. It does not appear likely, therefore, that the mere determination of total K_2O and Na_2O will always give a reliable index of the potential reactivity of a cement to be used with trouble-causing aggregate.

Types of Aggregates.

In the following list are given types of natural aggregates which may enter into expansive reaction in concrete; some of these materials would be undesirable apart from possible reactivity.

(1) Aggregate materials against which evidence is strong: (*a*) Opal and rocks containing opal, e.g. many flints, cherts and related rocks. (*b*) Volcanic rocks containing much volcanic glass and excessive amounts of very fine particles, e.g. andesite, rhyolite and felsite; porous and vesicular rocks will generally be

undesirable for this reason as well as on account of their physical properties. (*c*) Certain shales, phyllites and schists; such rocks also possess objectionable physical properties. (*d*) Selenite (gypsum) and other saline deposits.

(2) Aggregates against which there is some evidence: (*a*) Rocks containing olivine and its decomposition products, e.g. serpentine and chlorophæite. (*b*) Rocks containing decomposed felspar; this applies to igneous and metamorphic rocks and also to sediments, e.g. felspathic sandstones. (*c*) Rocks containing microcline-perthite felspar; this is surprising, as other felspars appear to be quite safe when fresh. (*d*) Zeolitic minerals.

"Colloidal" Concrete.

A new method of making and placing Portland cement concrete, known as the "Colcrete" process, has been developed in the past few years by Mr. J. S. Morgan, M.Sc., and Mr. J. C. Gammon, O.B.E., B.Sc., A.C.G.I. The process is based on the increased fluidity of cement-sand mortar which results from mixing cement and water in a colloidal mill, and on the absence of separation of the liquid and solid particles which occurs in the case of cement slurries mixed in the usual way.

In the new process two separate mixing tanks are used. In one of these tanks the cement and water are mixed to form a cement-water colloidal grout. This mixture is passed to the second tank, where sand passing a $\frac{3}{16}$-in. sieve is added and mixed with the grout and, after mixing, pumped through a pipeline for delivery to the work. The tanks and petrol-driven power unit are mounted on a two-wheeled chassis. Each mix contains 1 cwt. of cement, and sixty mixes per hour are obtained. The mixture is delivered to the pipe at a head of 30 ft. (equivalent to a head of 60 ft. of water); a length of pipeline greater than 150 ft. is not recommended; the internal diameter of the hose is $2\frac{1}{4}$ in., and the pressure at the discharge end can be regulated by prolonging the period of discharge from the mixer.

Two main methods, known as the direct and reverse processes, are available. In the direct process, coarse aggregate, which can be of any size provided it contains no particles less than $\frac{3}{4}$ in., is first placed and the voids filled with grout. In the reverse process, coarse aggregate, which must be free from very small grit or sand, is poured into the grout. A combination of the two processes is used in which the reverse process is applied only to the upper $1\frac{1}{2}$ in. of the concrete; thereby the voids in the aggregate are reduced to about 36 per cent. With an output of the mixer of 156 cu. ft. per hour, the output of finished concrete would be 16 cu. yd. per hour.

The process is chiefly used for roads, floors, and other slabs laid on the ground of any normal thickness, and the grout is applied by moving the discharge end of the hose over the coarse aggregate already laid until all the voids are filled and the grout appears at the surface. The concrete surface is then screeded in the usual way. In vertical work it is necessary to pour the grout through metal tubes passing through the aggregate if a considerable depth is being placed

at one time. The procedure is first to place the reinforcement, then to pack the stone into the shutters, and finally to apply the grout ; no ramming or tamping is necessary. So far, however, very little work has been done in vertical shutters. In mass concrete work, it is stated that the grout penetrates satisfactorily to a depth of 3 ft. without special precautions provided that none of the stone is smaller than 1 in. For underwater work the grout is introduced through a pipe into the bottom of the stone, displacing the water without admixture with it, and is claimed to form a solid impermeable concrete free from honeycombing.

Among the advantages claimed for the process in road work are the following :

One machine will grout 500 sq. yd. of 6-in. roadway in an 8-hour day. Two machines working a double shift would grout a mile of road 20 ft. wide in a week.

The uniform quality of the work does not depend on ramming or tamping. Rain does not affect the work.

Only about one-quarter of the materials which are mixed in an ordinary concrete mixer are dealt with ; the coarse aggregate is dumped direct where it is wanted.

The use of the plant, including depreciation, does not exceed 1*d*. per sq. yd. of work completed.

Any sand of good quality is suitable. Coarse aggregate of extra large size can be used. Also aggregates such as soft sandstones, soft limestones, and broken brick can be used for the body of the work.

The compressive strength is said to satisfy standard specifications and to be very uniform. The abrasive resistance is stated to be in general double that of normal concrete.

Expansion joints can often be eliminated or reduced. The aggregate is packed to capacity within the forms and cannot shrink. The result, after grouting, is a concrete much less subject to shrinkage than normal concrete.

Compared with normal methods there is a saving in plant, labour, sand, and cement.

The licensees for the process are Colcrete, Ltd., for the metropolitan area of London ; Mulcaster and Co. (Contractors), Ltd., for Cheshire ; Leonard Fairclough Ltd., for Lancashire ; and the Cementation Co., Ltd., for other districts. Mr. J. C. Gammon has been elected a director of the Cementation Co., Ltd.

MISCELLANEOUS ADVERTISEMENTS.

SCALE OF CHARGES.

Situations Wanted, 1½d. a word ; minimum 3s. 6d. Situations Vacant, 2d. a word ; minimum 5s. Box number 6d. extra. Other miscellaneous advertisements, 2d. a word, 5s. minimum.

Advertisements must reach this office by the 5th of the month of publication.

LIME ASH at BUXTON. Hundreds of thousands of tons available for getting by Agricultural Contractors. Apply Thos. W. Ward, Ltd., Albion Works, Sheffield.

TIME RECORDERS (weekly card type). Ideal for large or small staffs. Delivery three weeks. Inquiries invited. Commercial Recorders, Ltd., 6, Park Sq., Leeds, 1.

Cement Kilns for Sintering Iron Ore.

With the object of making use of all idle plant a number of cement kilns, some of them of obsolete design, are now producing lime, sintered ores, phosphate, and bauxite. In view of the possibilitiy that more cement kilns may become idle as essential construction work is completed, the problem of converting cement plant to other products is discussed in " Rock Products " for August, 1943, by Mr. A. B. Anderson, of Messrs. F. L. Smidth and Co., of New York.

The author points out that the equipment in a cement plant which is of interest in this connection is, generally speaking, crushers, grinding mills, and rotary kilns. In rare cases flotation equipment also may be available. Idle machinery in all these categories may be used in the war effort, but the idle machine which is of prime importance is the rotary kiln, while the crushers and grinding mills may be considered as more or less auxiliaries which are required by some processes and not by others. Rotary kilns, in all essential features similar to the rotary kilns used by the cement industry, are used in the manufacture of iron and steel, manganese, nickel, alumininum, magnesium, zinc, tin, lime, refractories, phosphates, and dolomite. This article is confined to one of the most important processes to which the cement plant may be converted, namely, the process of agglomerating iron-ore fines, blastfurnace flue dust, and other iron-bearing materials, and the conversion to this process is in most cases extremely easy to undertake.

The expansion of the steel industry has tremendously increased the demands of blastfurnace and open-hearth operators for larger quantities of iron-ore sinter or nodules. The blastfurnace is charged with a mixture of iron ore, coke, and limestone. The iron-ore has to be sized so that an adequate surface is presented to the reducing gases, and at the same time offers suitable resistance to the blast. In order to avoid blowing ore out with the blast, sizes smaller than $\frac{1}{16}$ in. to $\frac{1}{8}$ in. and dust cannot be charged into the blastfurnace without prior treatment. To render such fines and dust suitable for treatment in the blastfurnace, they are sintered or nodulised ; that is, the ore particles are heated to a suitable temperature, whereby they are partly fused and bound together. It is now generally recognised that increased capacity, lower fuel consumption, and improved operation of the blastfurnace result from the use of increased quantities of sintered or nodulised ore. By using sintered or agglomerated ore on a larger scale, it is also possible to use treated ore, as well as various by-products rich in iron that are frequently obtained in a finely-divided state and cannot be used in the blastfurnace without prior treatment.

Nodulising in plain rotary kilns was undertaken more than thirty years ago. The main difficulty encountered was the tendency of the materials to adhere to the lining in the hot zone, causing the formation of " rings " which necessitated frequent shut-downs and otherwise interfered with efficient kiln operation ; consequently, special types of rotary nodulising kilns were developed in which provision was made for preventing the formation of rings and for their easy removal by scraper bars, etc. The presence of from 2 to 5 per cent. of carbon in the feed

to a nodulising kiln normally makes it possible to obtain a substantially increased output. The presence of carbon is particularly important if low-grade fuel, such as blastfurnace gas, is used for heating the kiln. Where iron-ore fines are nodulised together with flue dust, the two materials may be proportioned in such a way as to provide the desired carbon content ; where only iron-ore fines are nodulised the carbon is added in the form of carbonaceous material such as coke breeze or coal screenings.

The company with which the writer is identified has investigated means of rendering the plain rotary kiln suitable for nodulising. The results have so facilitated kiln operation that plain cement kilns may now, with minor modifications, be satisfactorily used for this purpose. The process uses a so-called agglomerating agent, of which a minor quantity is mixed with the ore. The melting temperature of the agglomerating agent is considerably lower than the melting temperature of the ore itself. The mixture of agglomerating agent and ore is heated to a temperature that is slightly above the melting point of the agglomerating agent and considerably below the melting point of the ore. The agglomerating agent melts and binds the ore-particles into nodules. The usefulness of the method has been thoroughly established in laboratory kilns, and also by a large-scale test sponsored by the Government at a cement plant in the East. Another method of obtaining improved nodulisation has been developed by the Universal Atlas Cement Co., and is now in use in some cement plants. The method is based on the addition of crushed limestone to ores which are low in lime.

The agglomerating agent used in the first-mentioned method is made from a mixture of iron ore and limestone ground together in a mill to a fineness of, say, 90 per cent. through a 200-mesh sieve. For example, if the limestone available has a calcium carbonate content of 90 per cent., and if the ore to be sintered is haematite with, say, 55 per cent. Fe, the agglomerating agent would be made by grinding a mixture of 20 to 25 per cent. limestone to 75 to 80 per cent. iron ore. The control of the mix is effected by titration of the carbonate in a manner similar to that by which a cement raw mix is controlled, the difference being that, in preparing the agglomerating agent, greater fluctuation in composition may be permitted than in a cement raw mix.

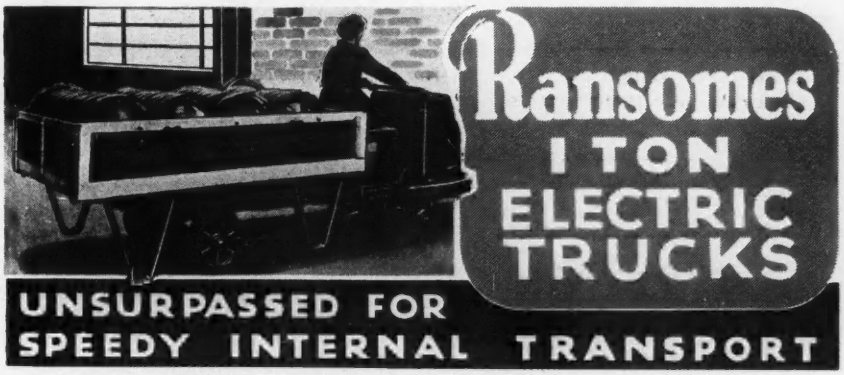
The agglomerating agent may be made wet or dry according to the cement plant in question. In a wet process plant, the agglomerating agent would probably be made as a slurry containing the normal amount of water, stored in the slurry tanks, and pumped by the slurry pumps. In a dry process plant the agglomerating agent may be handled by the ordinary equipment in the cement plant.

Usually cement raw materials are conveyed from the storage to the grinding plant, and in preparing the agglomerating agent the same means of conveyance can be used without modification. The major portion of the iron ore has to be conveyed directly from the storage to the kiln. In ordinary circumstances, a system of belt conveyors and elevators will be needed for this purpose. In most cases, however, the installation of conveying equipment for the iron ore to the kiln can be made at small cost.

Normally, the iron ore should be fed to the kiln through a pipe 14 in. to 24 in. in diameter. The agglomerating agent, whether in the form of slurry or dry, can be fed to the kiln by the usual means with which the raw mix is fed to the kiln. Suitable means of controlling the proportions of ore and agglomerating agent should be provided. The temperature in the burning zone, or nodulising zone, should be between 2,200 and 2,300 deg. F. There are no special requirements for the lining in the kiln and, owing to the relatively low temperature and absence of chemical reaction in the burning zone, the wear and tear on the firebrick is small.

It is estimated that the output of nodules will be between three and four times as high as the output of clinker. The kiln must produce its maximum output of nodules and frequently an increase in the speed of the kiln is needed to achieve this end. A suitable speed of the kiln for nodulising iron ore is from 1 to 3 r.p.m., depending on the diameter. Should the present arrangement of the kiln not permit such speed, the change will frequently require only a change of pulleys or a set of gears. The heat consumption per ton of nodules is about one-third to one-fourth of the heat consumption of a ton of cement clinker, and a satisfactory output of nodules may be obtained by using existing firing equipment to its full capacity.

The nodules leaving the nodulising zone of the kiln will harden immediately they are cooled to a temperature below 2,100 deg. F. Most cement kilns are provided with coolers, and in most cases these coolers, or with slight modifications,



★ **These are the reasons why :—**

1. Up to 100 tons, according to distance, can be moved from one department to another on ONE BATTERY CHARGE (8 units).
2. A full load can be transported at a speed of 7 m.p.h.
3. The truck is particularly suitable for female labour. The driver is comfortably seated, operation is extremely easy, and fatigue eliminated.
4. Simple design and robust construction make a Ransomes 1-tonner virtually foolproof.

Fixed or elevating platform types can be supplied. Let us send you particulars of these, and our range of 2-ton electric trucks. Write to Dept. C.L.

RANSOMES SIMS & JEFFERIES LTD. ORWELL WORKS, IPSWICH

can be used for handling the hot nodules. It is important that the nodules contain as little fines as possible, and therefore the handling of the nodules should not be severe. If a cement plant is provided with an underlying rotary cooler provided with lifters, etc., such lifters should be removed because rough handling by the lifters is apt to cause excessive wear on the nodules, thereby producing undesirable fines. The capacity of the existing coolers will normally be adequate. The amount of nodules is much greater than the amount of cement clinker produced, but the heat in the nodules is lower than the heat in the corresponding amount of cement clinker. Generally, however, in order to produce nodules as economically as possible the maximum output is of far greater importance than minimum fuel consumption. Therefore, from a heat-recovery standpoint, the nodules can be discharged from the cooler at a considerably higher temperature than is normally maintained for cement clinker. The requirements are that the nodules should be sufficiently cooled to be loaded directly into open steel wagons for transport to the steel plants.

If a cement plant has no facilities for loading directly from the cooler into the railway wagons, it will be necessary to build a conveyor to take the nodules directly from the cooler to railway wagons. The conveyor should be suitable for handling hot material.

THE SUPERVISION OF CONCRETE WORK

Because there is no doubt that a better understanding, on the part of those carrying out concrete work, of the properties of concrete and reinforced concrete, and of the causes of unsatisfactory work, will lead to an improved standard of workmanship, a book entitled "An Introduction to Concrete Work" has been published by Concrete Publications, Ltd. (14, Dartmouth Street, London, S.W.1). It is pocket size, contains 144 pages and 116 illustrations, the price is 1s. 8d. by post, and it is written so that it can be readily understood by boys leaving an elementary school. The aim of the author is to give an understanding of the properties of concrete and its constituent materials, a knowledge of the theory of reinforced concrete, and an outline of modern methods of concrete construction. Instructors at technical schools should consider the merits of this work as a text book on concrete for junior students.